Lecture 1: Introduction

Thursday, October 1, 2020 9:14 AM

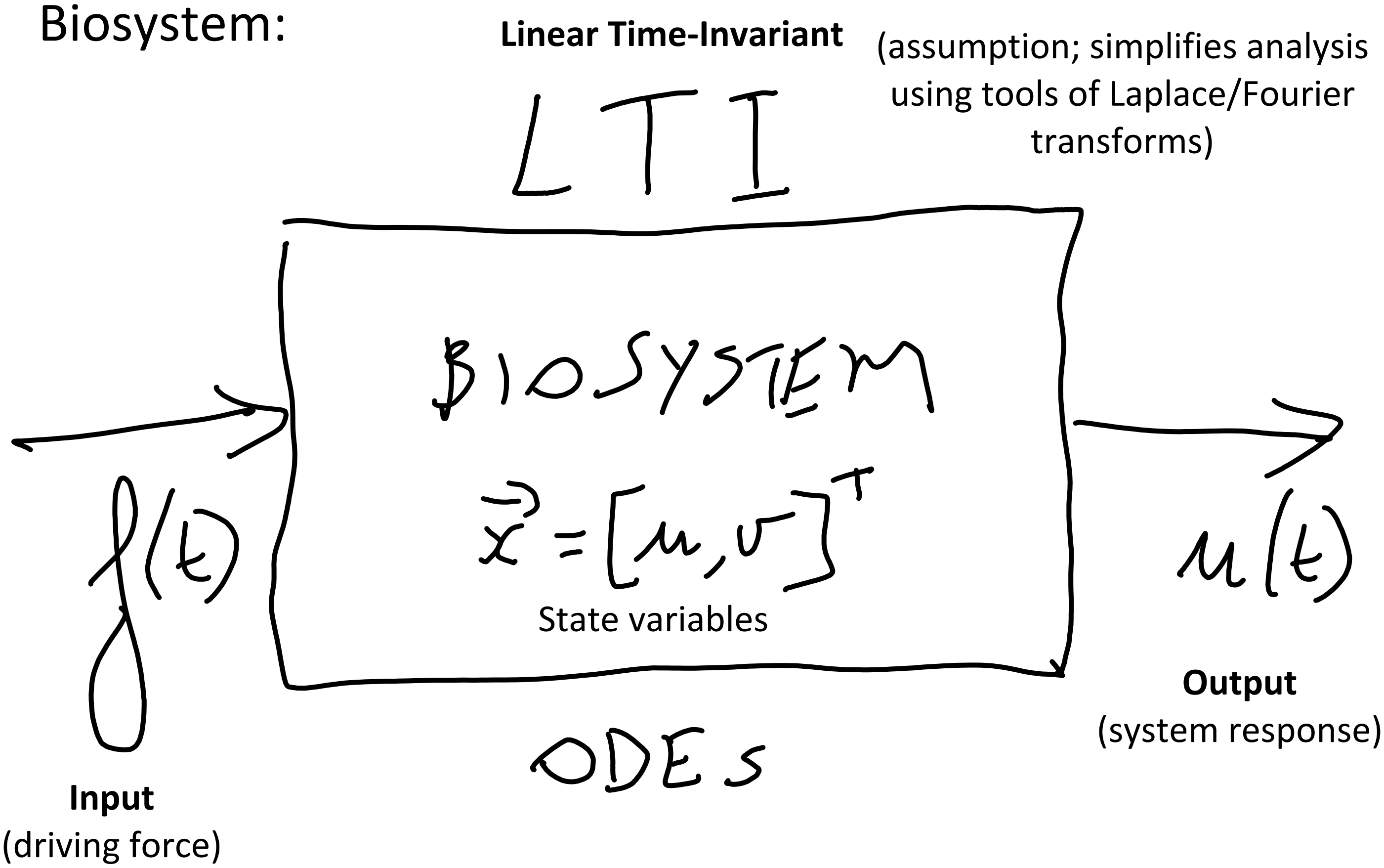
References:

Tranquillo JV. *Biomedical Signals and Systems*, Morgan & Claypool Publishers, Dec. 2013. Chapters 1 & 2

Coughanowr DR & LeBlanc SE. *Process Systems Analysis and Control*, 3rd Ed., McGraw-Hill, 2009.
Chapter 1

de Canete JF, Galindo C, Barbancho L and Luque A. *Automatic Control Systems in Biomedical Engineering*, Springer 2018.
Chapters 1 & 2

Biosystem:



$$
\begin{cases}
\dfrac{du}{dt} = \dots(f, u, v) \\
\dfrac{dv}{dt} = \dots(f, u, v)
\end{cases}
$$

Dynamics of the state variables of the system described by a set of ordinary differential equations (ODEs)

$$
\frac{d\vec{x}}{dt} = \vec{F}(f, \vec{x})
$$

Same, in vectorial notation

Examples in bioengineering:

Input (driving force)	**Biosystem** (internal state dynamics)	**Output** (system response)
insulin	blood	glucose level
force	limb	motion
pacemaker signal	heart	ECG rhythm

Outline of the course:

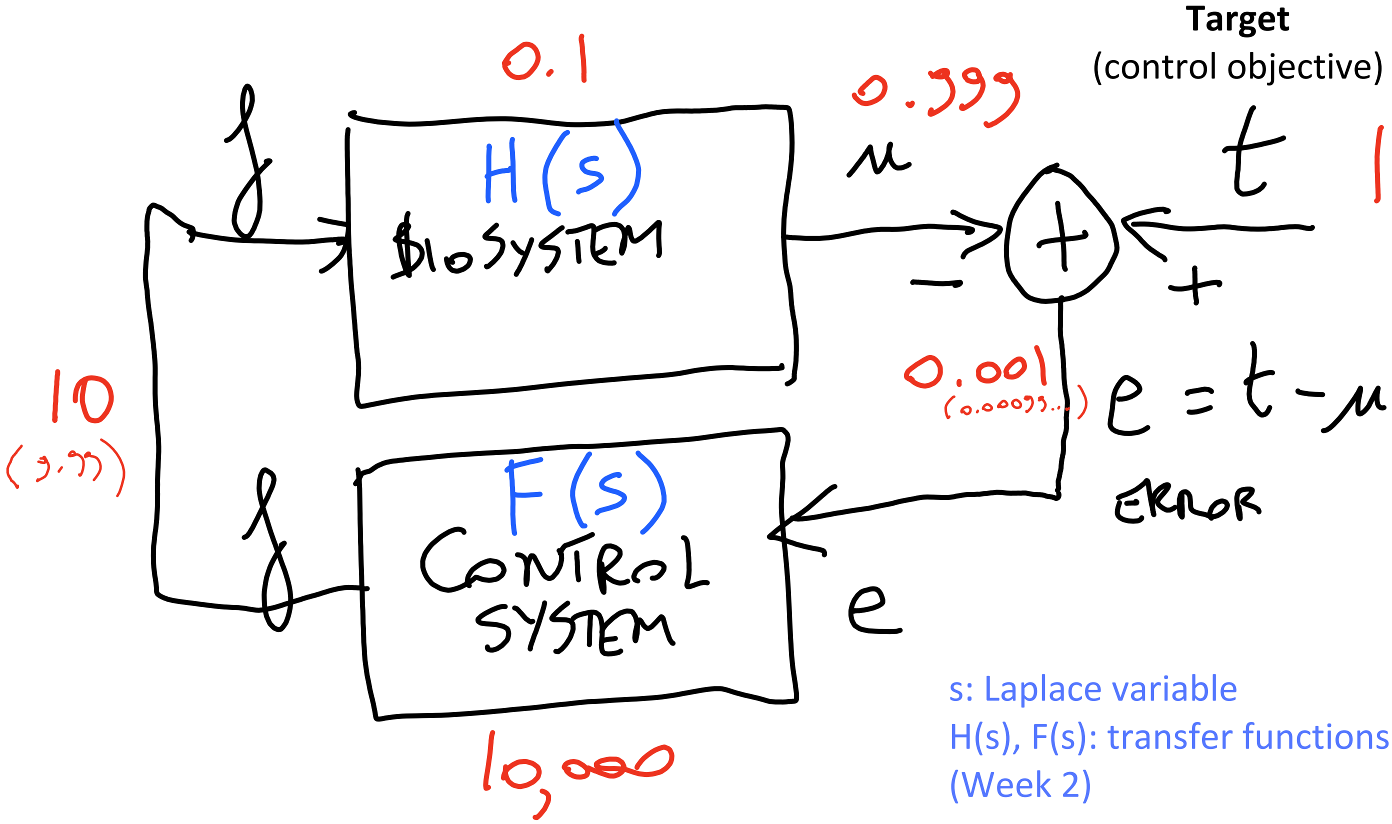
1. [Weeks 1-3] Model biosystems to characterize the dynamics of input-output relations, and analyze their stability using tools of linear systems analysis. To bioengineers, this provides understanding of what factors affect health and lead to disease.

2. [Weeks 5-7] Design control systems that drive biosystems towards desirable states with stable dynamics. To bioengineers, this provides systematic means to regulate biosystems to improve health and remediate disease.

3. [Weeks 8-10] Case studies in bioengineering control systems design, including emerging topics in bioinspired and neuromorphic systems engineering. Final project.

Feedback and control in a nutshell:

(a teaser and motivator; more in Weeks 3-7)



High-gain negative feedback

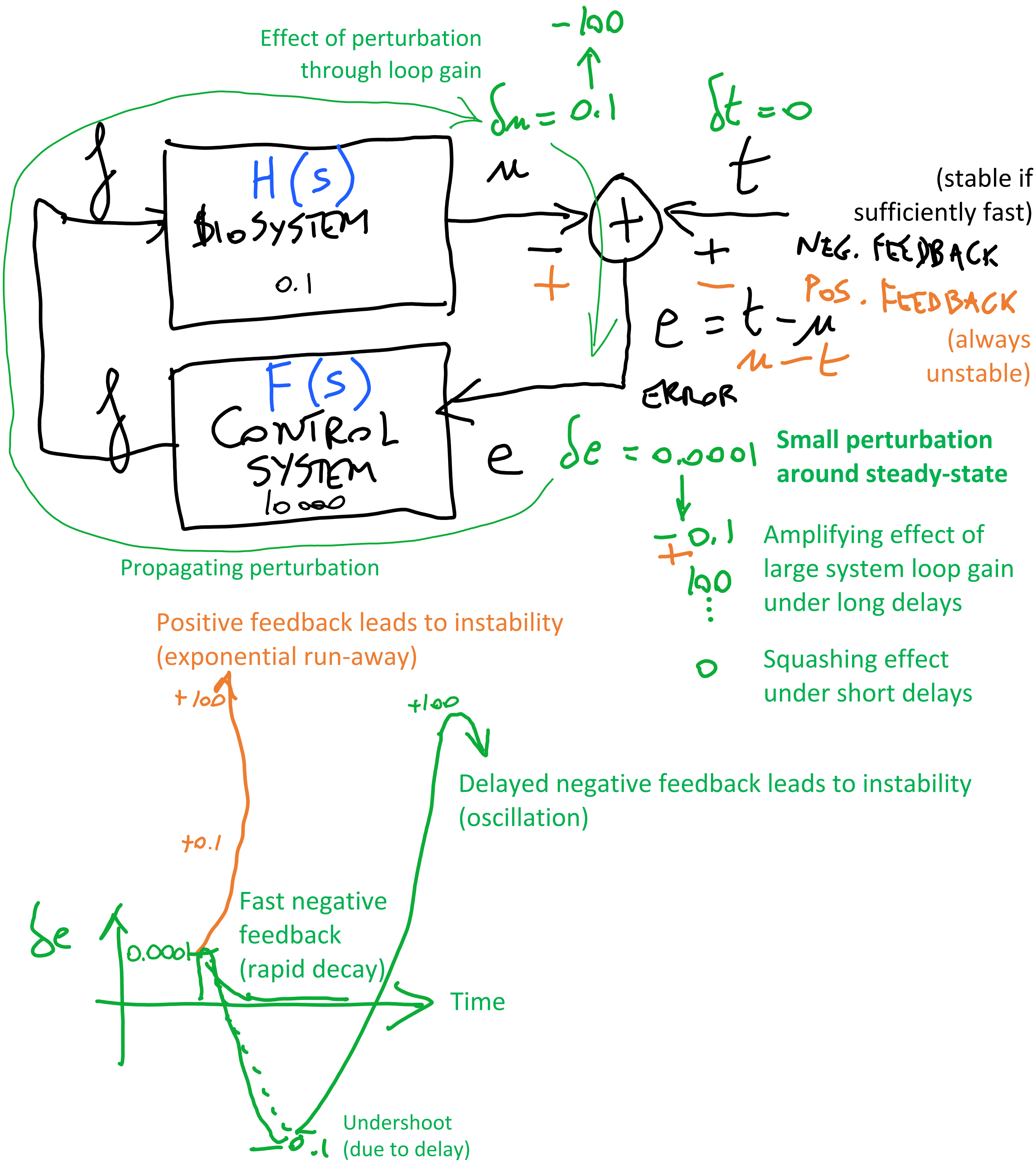
$$u = F \cdot H\,(\underbrace{t - u}_{e})$$

$$(1 + FH)\,u = FH\,t$$

$$u = \frac{FH}{1 + FH} \cdot t = \frac{1}{1 + \frac{1}{FH}} \cdot t$$

$$\Rightarrow \underset{1{,}000}{FH} \to \infty \text{ in order for } \underset{0.999}{u} \to \underset{1}{t}$$

Problem with high-gain feedback control:
stability under influence of system delays:



Takeaway: dynamical systems are complex, and control is hard! Before we may attempt the systematic design of effective control systems, we need a fundamental understanding of the dynamic response and stability of linear systems, using tools of linear analysis and linear transforms (Weeks 1 & 2).